INDOOR AIR QUALITY ASSESSMENT

Winthrop Elementary School
162 First Street
Melrose, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of Karen Springer of the Melrose Health Department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Winthrop Elementary School, 162 First Street, Melrose, Massachusetts. Concerns about poor indoor air quality and heat complaints prompted this request.

On May 4, 2001, a visit was made to this school by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Ms. Springer for part of this assessment.

The school is a two-story brick structure. The original school building was constructed around 1926 (the 1926 section)(see Picture 1). An addition was constructed in 1956 (the 1956 section) (see Picture 2). Windows are openable throughout the building. Energy efficient windows were installed throughout the building.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551.

Results

The school has a student population of 900 and a staff of approximately 40. The tests were taken during normal operations at the school. Test results appear in Tables 1-3.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million of air (ppm) in sixteen out of twenty eight areas surveyed, indicating a ventilation problem in the building. Please note that rooms with carbon dioxide levels below 800 ppm either were unoccupied or had windows open. Classrooms 1, 2 and the art/music room had carbon dioxide levels over 2,000 ppm, indicating little or no air exchange. The ventilation system in the original building was not operating during the evaluation. Carbon dioxide levels in the building would be expected to be higher during winter months, when windows are closed, due to the configuration and condition of the ventilation system.

Two distinct ventilation systems exist in this building. Fresh air is provided in the 1926 section building by an air handling unit (AHU) located in a large room on the ground floor that is connected to ductwork leading to air diffusers (see Picture 3). Fresh air is drawn into the building through a vent at the rear of the building. Air is drawn through heating elements (see Picture 4) into a fan unit that distributes the air via wall mounted fresh air grilles throughout the 1926 section. Classroom fresh air supply grilles are connected to the fan unit by ductwork located in a crawlspace beneath the 1926 section. This ventilation system appears to have been abandoned as part of an energy conservation project due to the following conditions noted throughout the 1926 section.

1. All fresh air intakes were sealed with plywood (see Picture 5 and 6).
2. The original fresh air intake outside the heating element room was sealed with energy efficient windows (see Picture 7).
3. The air intake for the fan unit that draws air through the heating elements is sealed with plastic (see Picture 8).
4. The fan belt connected to the motor that drives the fan unit was removed (Picture 9).
5. Interior hallway door transoms were removed and sealed with plywood.

These alterations have resulted in open windows serving as the sole source of fresh air in the 1926 section.

The 1956 section classrooms have fresh air supplied by a unit ventilator (univent) system. A univent draws fresh air from a vent on the exterior of the building and air from the classroom (called return air) through a vent in the base of its case (see Figure 1). Fresh air and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents were operating; however the introduction of fresh air appears to be minimized as demonstrated by the carbon dioxide measurements in classrooms, particularly the ground floor. Obstructions to airflow, such as boxes and tables blocking univents, were seen in a number of classrooms. In order for univents to provide fresh air as designed, fresh air diffusers and univent returns must be unblocked and remain free of obstructions.

The 1926 section's exhaust system appears to depend on air pressurization to force air into classroom vents that exit the building through louvered vents located on the roof. Without the fresh air supply system operating, exhaust ventilation from classrooms will be minimized. Some of the louvers are closed. The exhaust vent on the southernmost section of the roof has louvers frozen open. Louvers open in this manner may allow for cold air to backdraft into classrooms overnight and during cold daytime weather in the winter. Building occupants reported that cold conditions in classrooms are a chronic problem.

The only means for creating airflow in this building is using openable windows. Rooms in the 1926 section are heated using wall-mounted radiators. During summer months, ventilation in the school is controlled by the use of openable windows in classrooms. This section was configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. This hinged window (called a transom) enables classroom occupants to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through a classroom and subsequently pass through the open transom. Airflow then enters the hallway, passing through the opposing open classroom transom, into the opposing classroom and finally exits the building on the leeward side (opposite the windward side) (see Figure 1). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. This system fails if the windows or transoms are closed (see Figure 2). Rooms that are not opposite other classrooms would have increased difficulty in creating cross ventilation and would need some means to increase air movement (e.g., floor fan in an open window). Transoms appear to be sealed as part of the energy conservation program. In order to create airflow, hallway doors need to be opened. BEHA staff could open windows in several classrooms. However, BEHA staff experienced great difficulty in closing windows. This condition could result from warping of either the sash or window frame. Teachers would experience as much difficulty adjusting window openings. In addition, upper sash windows are left open overnight in order to air out the interior of the classroom. This practice is of limited value since the upper sashes of windows are blocked with cloth/curtain materials that restrict airflow. Open windows may also allow for rainwater to penetrate through windows. Pests, such as birds, bats and insects, also have access to the interior if windows are left open overnight.

Some rooms in and around the cafeteria foyer that are used as classrooms have neither fresh air supply or exhaust ventilation. These rooms also do not have an openable window; therefore no air exchange exists in these rooms.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Temperature readings ranged from 77^{o} F to 89^{o} F on an unseasonably hot day in the first week of May (with an outdoor temperature of 91^{o} F), which were above the

BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is difficult in an old building without a functioning ventilation system.

The relative humidity ranged from 33 to 49 percent. Most areas sampled were within the BEHA recommended comfort range (see Tables). The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity in this building would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment Relative humidity levels in the building would be expected to drop during the winter months due to heating. It is important to note however, that relative humidity measured indoors exceeded outdoor measurements (range +8-23 percent). This increase in relative humidity can indicate that the exhaust system alone is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). Moisture removal is important since the sensation of heat conditions increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperature rises, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. Removal of moisture from the air, however, can have some negative effects. The sensation of dryness and irritation is common in a low relative humidity environment.

Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several classrooms contained a number of plants. Plant soil and drip pans can serve as a source of mold growth. A number of these plants did not have drip pans or were in outdoor type planters with no drainage. When used indoors, the lack of drip pans and drainage can lead to water pooling and mold growth on windowsills. Wooden sills can potentially be colonized by mold growth and serve as a source of mold odor.

Several classrooms have sinks that have a seam between the countertop and wall. Water can penetrate the countertop seam if it is not watertight and collect. Water penetration and chronic exposure to water on wood, plywood and corkboard cause these materials to swell and serve as a growth medium for mold.

A greenhouse exists off the auditorium/cafeteria. Upon entering the greenhouse, the odor of mold was detected. Planting benches in this area are made of wood and have no discernible means for water drainage. Soil in contact with water and wood can result in mold colonization of the wooden planter boxes, which can then serve as a source of mold. In order to prevent mold growth, appropriate water drainage from soil and soil aeration is necessary. The greenhouse did not have local exhaust ventilation. Local exhaust ventilation would aid in the control of odors and relative humidity.

Bird Wastes and Other Concerns

Of primary note was the accumulation of possible bird wastes observed inside the exhaust vent system (see Picture 10 and 11). Bird wastes in a building raise concerns over diseases that may be caused by exposure to bird wastes. These conditions warrant clean up of bird waste and appropriate disinfection. Certain molds are associated with bird waste and are of concern for immune compromised individuals. Diseases of the respiratory tract may also result from exposure to bird waste. Exposure to bird wastes is thought to be associated with the development of hypersensitivity pneumonitis in some individuals. Psittacosis (bird fancier's disease) is another condition closely associated with exposure to bird wastes in bird raising and other occupational settings. While immune compromised individuals have an increased risk of health impacts following exposure to the materials in bird wastes, these impacts may also occur in healthy individuals exposed to these materials.

The methods to be employed in clean up of a bird waste problem depends on the amount of waste and the types of materials contaminated. The MDPH has been involved in several indoor air investigations where bird waste has accumulated within ventilation ductwork. Accumulation of bird wastes have required the clean up of such buildings by a professional cleaning contractor. In less severe cases, the cleaning of the contaminated material with a solution of sodium hypochlorite has been an effective disinfectant (CDC, 1998). Disinfection of non-porous materials can be readily accomplished with this material. Porous materials contaminated with bird waste should be examined by a professional restoration contractor to determine if the material is salvageable. Where a porous material has been colonized with mold, it is recommended that the material be discarded (ACGIH, 1989).

The protection of both the cleaner and other occupants present in the building must be considered as part of the overall remedial plan. Where cleaning solutions are to be used, the “cleaner” is required to be trained in the use of personal protective methods and equipment (to prevent either the spread of disease from the bird wastes and/or exposure to cleaning chemicals). In addition, the method used to clean up bird waste may result in the aerosolization of particulates that can spread to occupied areas via openings (doors, etc.) or by the ventilation system. Methods to prevent the spread of bird waste particulates to occupied areas or into ventilation ducts must be employed. In these instances, the result can be similar to the spread of renovation-generated dusts and odors in occupied areas. To prevent this, the cleaner should employ the methods listed in the SMACNA Guidelines for Containment of Renovation in Occupied Buildings (SMACNA, 1995).

The abandoned ventilation system can also serve as a pathway for basement particulates and odors to migrate into occupied areas of the 1926 section. In general, cold air migrates to areas with heated air, thereby creating drafts. The temperature in the heating coil room will generally be lesser than the occupied areas of classrooms, therefore colder basement air will move to classrooms via the vent system if means of access (holes, open access doors) exist in the ductwork. In this instance, pathways for basement air, odors and particulate matter exist. An access door to the vent system was open in the ductwork (see Picture 12). An access door to the 1926 section crawlspace was open inside the fan room (see Picture 13). In addition, holes in ductwork inside the dirt crawlspace beneath the 1926 section were also observed. With the removal of plywood sealing each fresh air vent, a pathway for crawlspace pollutants to migrate into classrooms has been established.

Filters installed in univents provide minimal respirable dust filtration. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase of filtration, univents should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters. Lastly, a photocopier is located in an unventilated room. Volatile organic compounds (VOCs) and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992). Local exhaust ventilation may be needed in this area to help reduce excess heat and odors.

A wall that consists of a white, powdered material was found in the basement (see Picture 14). The material may contain asbestos and should be remediated in conformance with all applicable Massachusetts asbestos abatement and hazardous materials disposal laws.

Conclusions/Recommendations

The energy conservation renovations to this building have essentially removed any means to provide mechanical ventilation for the 1926 section. It is highly likely that univent fresh air intakes were blocked, since carbon dioxide levels in the 1956 sections were substantially above comfort levels. In addition, blocking fresh air intakes was a standard energy conservation practice. This minimization of airflow into the building can result in environmental pollutants to concentrate in occupied areas. In addition, the pathways of reverse airflow from exhaust vents along with air from the basement exist in these classrooms.

In order to address the conditions listed in this assessment, the recommendations made to improve indoor air quality in this building are divided into short-term and long-term corrective measures. The short-term recommendations can be implemented as soon as possible. Long-term solution measures are more complex and will require planning and resources to adequately address the overall indoor air quality concerns within this school.

Short Term Recommendations

1. Clean wastes from the exhaust vents on roof.
2. Install wire around openings of exhaust vents to prevent bird/bat roosting.
3. Repair windows to allow for easy opening and closing by occupants. Use open windows to provide fresh air as needed.
4. Close all access doors in abandoned ductwork and crawlspaces.
5. Render airtight all holes/seams in ductwork.
6. Reseal all fresh air supply vents with plywood.

7. Use the sash windows in air mixing rooms to introduce fresh air into the building.
8. Use open windows and hallway doors to enhance airflow during warm weather. Be sure to close windows and doors at the end of the school day. To aid in the draw of fresh outdoor air in warm weather, use portable fans directing air out windows on the leeward side of the building. Fans positioned in this manner will serve to increase the draw of outdoor air across a floor without interfering with the natural, internal airflow pattern of the building. To aid cross ventilation, open hallway doors in areas with inoperable transoms.
9. Operating univents during hot weather will supplement the use of open windows. If sections of the ventilation system do not operate, the placement of fans to exhaust air from the leeward side of a building with hallway doors open may be employed.
10. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
11. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.

12. Seal the counter/backsplash seams with caulking to prevent water penetration around sinks.
13. Consider installing local exhaust ventilation in the photocopier area.
14. Ascertain whether material shown in Picture 14, contains asbestos and encapsulate or remove in conformance with Massachusetts law.

Long Term Recommendations

1. Consult a ventilation engineer to determine whether univents in the 1956 section can be repaired and restored to provide fresh air for classrooms. If not feasible, replacing the nonfunctioning univents should be considered.
2. If univents are repairable, consider increasing the filter efficiency after consultation with a ventilation engineer.
3. Consult a ventilation engineer to determine whether the deactivated ventilation system for the 1926 section can be repaired. Consideration should be given to installing an alternative mechanical ventilation system in this section of the school.
4. Consult a ventilation engineer to determine whether rooms now used as classrooms can be retrofitted with a mechanical ventilation system.
5. Examine the feasibility of installing exhaust ventilation for the greenhouse.

References

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Figure 1 **Cross Ventilation in a Building Using Open Windows and Transoms**

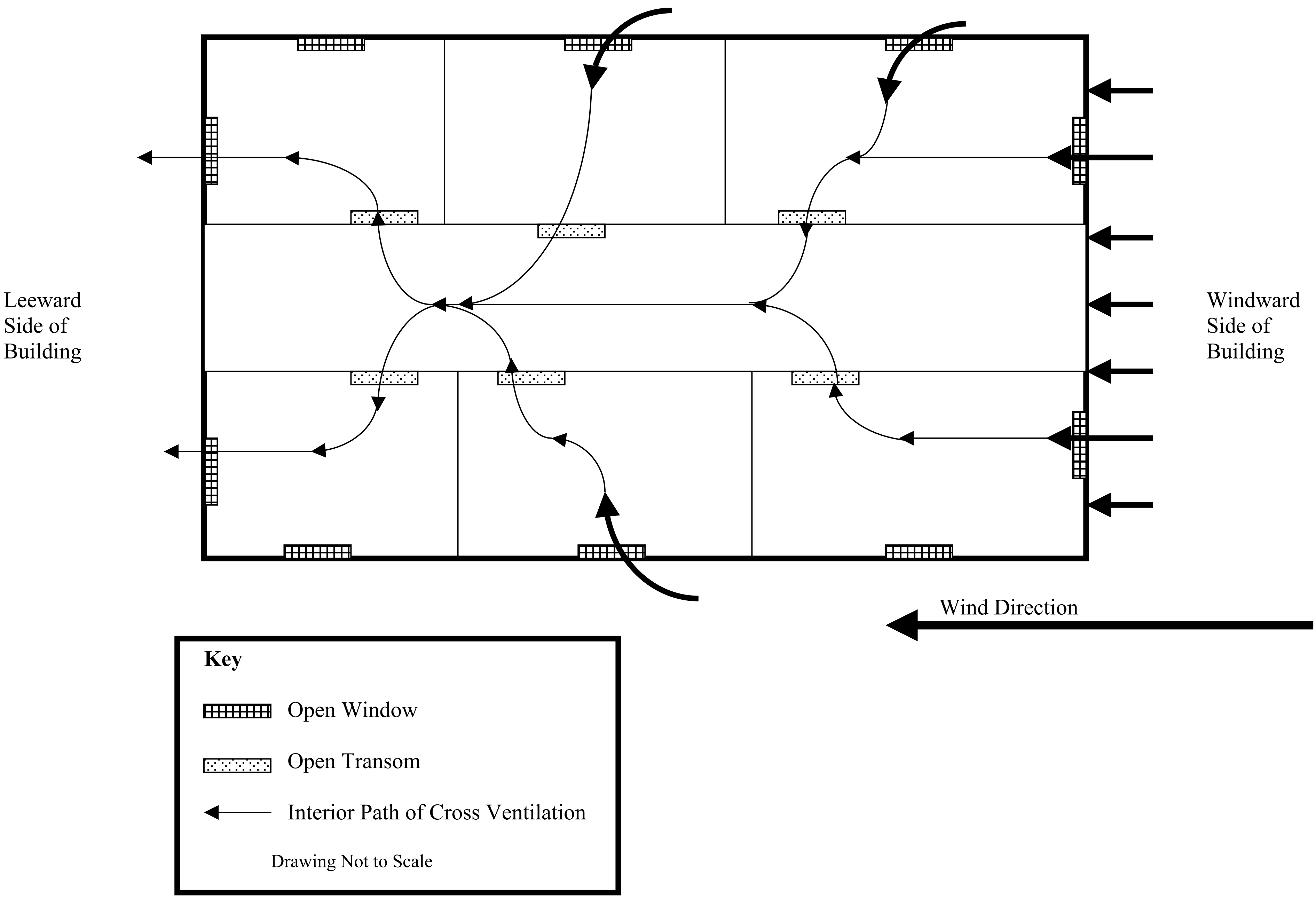
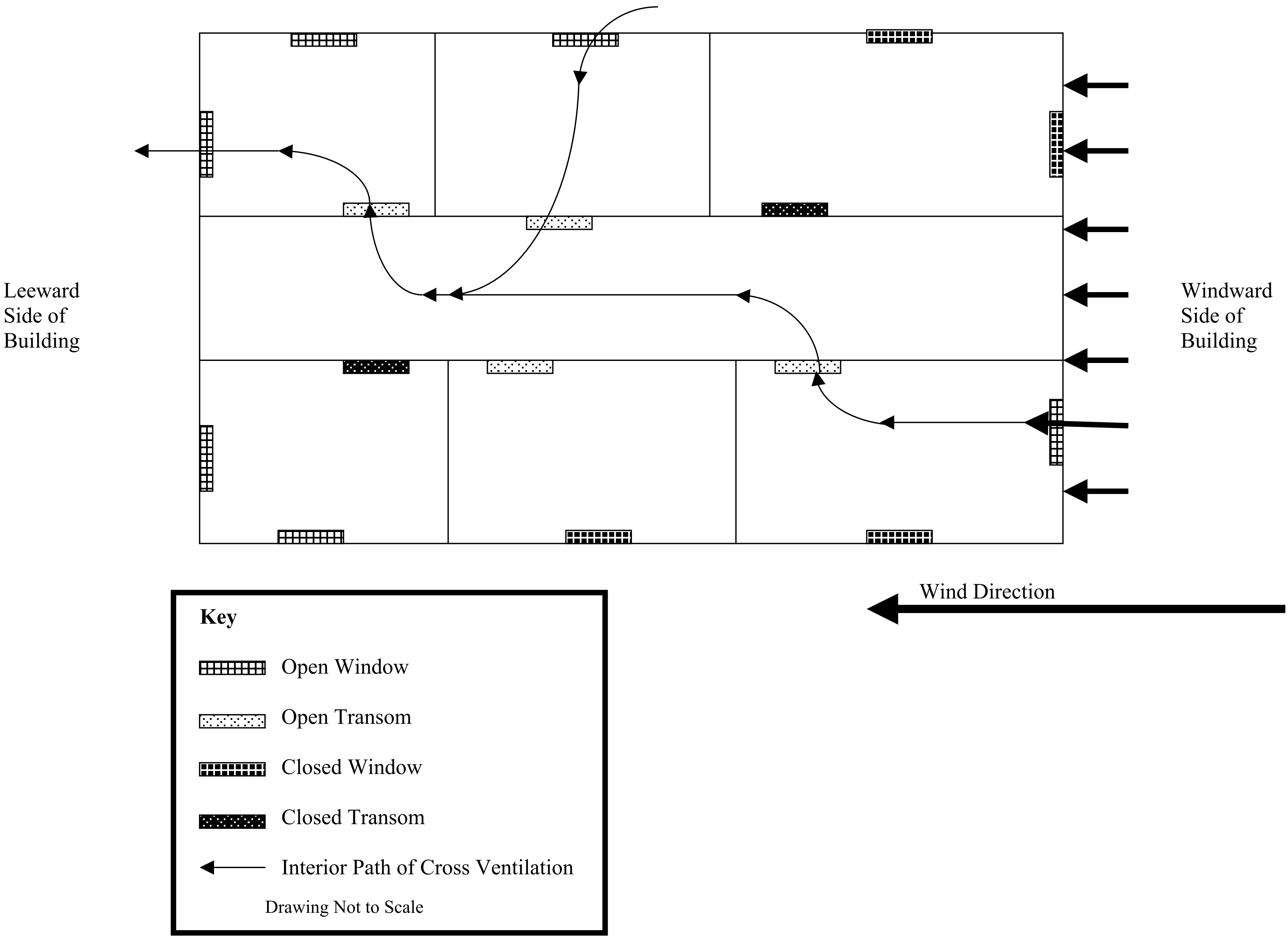


Figure 2 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**



Picture 1

1926 Section

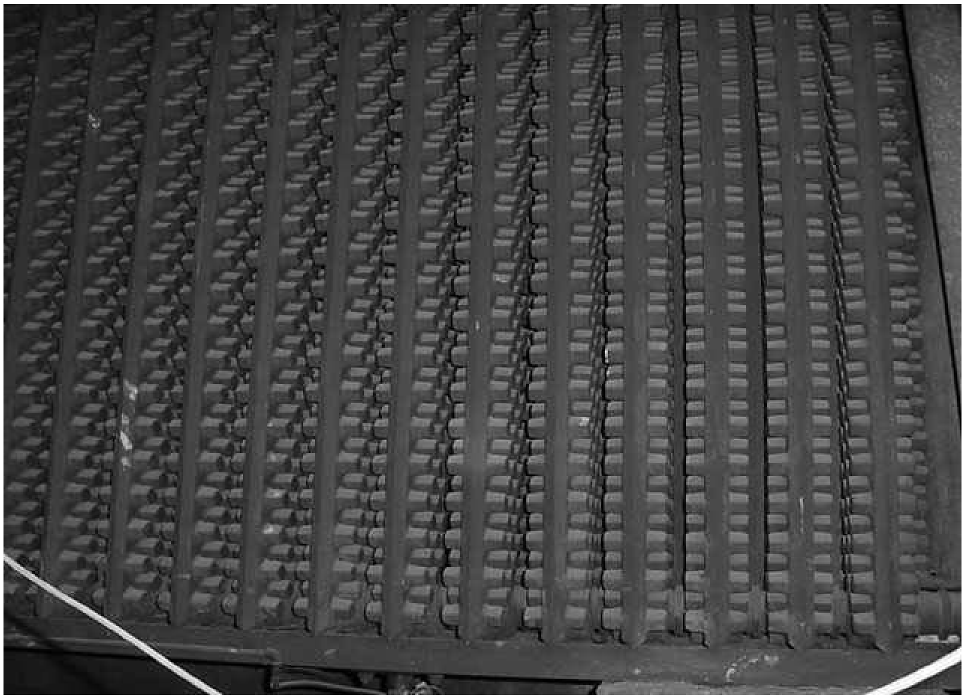
Picture 2

1956 Section

Picture 3

Fan Unit in Basement

Picture 4



Heating Elements in Basement AHU Room

Picture 5

Fresh Air Supply In 1926 Classrooms

Picture 6

Wood Residue On Fresh Air Intake Frame, Indicating That These Vents Were Sealed With Plywood

Picture 7

Former Fresh Air Intake Vent for Basement AHU Room, Now Sealed With Energy Efficient Windows.

Picture 8

AHU Air Intake Sealed With Plastic Sheets

Picture 9

Fan Motor with Fan Belt Removed

Picture 10

Exhaust Vent on Roof, Note Lack of Wire Screens to Prevent Pest Entrance

Picture 11

Accumulated Materials At Base Of Exhaust Vent Joints, Note Louvers Are In A Fixed Open Position

Picture 12

Open Duct Access Door in AHU Room in Basement

Picture 13

Open Crawlspace Access Door in AHU Room

Picture 14

Wall Material with Damage in Basement

TABLE 1

Indoor Air Test Results – Winthrop Elementary School, Melrose, MA – May 4, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Outside (Background)	478	90	25					
Classroom 30	576	84	37	4	Yes	Yes	Yes	Window and door open, transom closed,
Fitzpatrick	582	84	37	0	Yes	No	No	Photocopier, door open
Classroom 31	762	83	39	20	Yes	Yes	Yes	Supply and exhaust off-exhaust in closet, window and door open, plants
Classroom 32	824	84	40	22	Yes	Yes	Yes	Supply and exhaust off, window and door open, plants
Classroom 33	707	85	40	23	Yes	Yes	Yes	Supply and exhaust off, window and door open, water damaged plaster
Classroom 35	526	86	35	22	Yes	Yes	Yes	Exhaust blocked, window open
Classroom 36	655	86	30	23	Yes	Yes	Yes	Top windows open-blocked by shades, opposite janitor's closet
Library	584	86	34	0	Yes	Yes	Yes	Window and door open, exhaust blocked by cabinet
Classroom 37	477	87	33	20	Yes	Yes	Yes	Window open, cabinet

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide - < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems
Temperature - 70 - 78 °F
Relative Humidity - 40 - 60%

TABLE 2

Indoor Air Test Results – Winthrop Elementary School, Melrose, MA – May 4, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Classroom 38	828	87	36	21	Yes	Yes	Yes	Exhaust off, window open
Classroom 34	737	87	35	65	Yes	Yes	Yes	Window and door open
Classroom 22	1197	87	38	20	Yes	Yes	Yes	Supply off
Classroom 21	975	81	39	21	Yes	Yes	Yes	Supply and exhaust off, door open, water damage-sink
Teacher's Room	1017	79	35	2	Yes	Yes	Yes	Window mounted A/C, photocopier
Classroom 23	1090	80	47	17	Yes	Yes	Yes	
Classroom 24	625	76	37	23	Yes	Yes	Yes	Window open, see picture*
Classroom 25	790	84	40	24	Yes	Yes	Yes	
Classroom 26	1043	84	39	19	Yes	Yes	Yes	Window open
Classroom 27	802	85	37	22	Yes	Yes	Yes	Door open
Classroom 28	1045	85	40	19	Yes	Yes	Yes	

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Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 3

Indoor Air Test Results – Winthrop Elementary School, Melrose, MA – May 4, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Cafeteria	925	83	39	1	Yes	Yes	Yes	Supply and exhaust off
Classroom 1	2165	77	44	21	Yes	Yes	Yes	Supply off-plants near supply, water damage-sink, door open
Classroom 2	2477	77	45	20	Yes	Yes	Yes	Supply off
Art/Music Room	2705	77	46	21	Yes	No	No	
AV Room	1350	80	49	0	Yes	No	Yes	Exhaust off
Speech Room	1331	79	48	1	No	No	No	
Main Office	862	81	44	4	Yes	Yes	Yes	

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